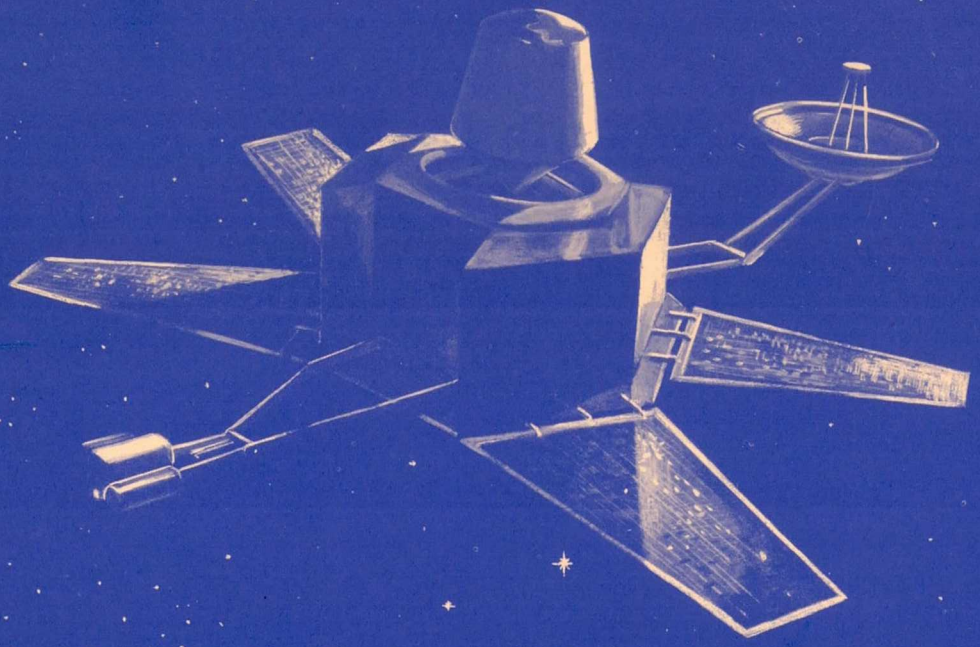
NASA EP-10

AMINO ACIDS
BIOLOGICAL RESIDUES
ENZYMES

THE SEARCH FOR EXTRATERRESTRIAL LIFE

LICHENS
PROTEINS
MACROMOLECULES
DNA
POLYPEPTIDES
MICRO-ORGANISMS



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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THE SEARCH FOR
EXTRATERRESTRIAL LIFE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, D.C.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 - Price 20 cents

MAN SEARCHES FOR LIFE IN SPACE

The mystery of his own origin has intrigued man since earliest antiquity. Throughout the ages he has puzzled and theorized over the question of how he began, where and when.

But man is a little like a detective arriving at the scene some millions or billions of years after the event—and trying to reconstruct the event. The principals have long since departed. Most of the clues have disappeared. Even the scene itself has changed.

Of equal fascination today is the question of life on other worlds—extraterrestrial life. Do the seasonal changes in color on the surface of Mars mean that plant life, at least, blooms, withers and dies there? Are there living things beneath the covering clouds of Venus, despite the great heat of this planet? Did life on the Moon go underground eons back when the atmosphere departed; and does life, or its residue, still exist there? Is Jupiter actually ice encrusted beneath its hydrogen shroud? And if it is, does this preclude some form of life undreamed of by man?

Now, for the first time, man is beginning to grasp the almost magic key which may solve the question of whether or not life in some form exists on the other celestial bodies of our solar system. The key is, of course, the technology of space exploration.

The search for life in space program now being carried out by the National Aeronautics and Space Administration is part of that technology.

The question of extraterrestrial life and the question of the origin of life are interwoven. Discovery of the first may very well unlock the riddle of the second. And understanding the second has innumerable implications for human health and disease.

The oldest form of fossil known today is that of a microscopic plant. It is similar in form to common algae found in ponds and lakes. Scientists know that organisms like it flourished and multiplied almost two billion years ago. But algae are a relatively complex form of life. It is therefore obvious that life in some simpler form originated much earlier.

By studying the radioactive decay of minerals, scientists have determined that the surface of the Earth hardened into something like its present form about four billion, five hundred million years ago. Life itself, they have decided, arose spontaneously a little later—about four billion, two hundred million years ago, plus or minus a few hundred million years.

Although the planets now have differing atmospheres, it is almost certain that in their early stages the atmospheres of all the planets were essentially the same.

Primitive earth's atmosphere consisted of extremely hot gases, probably including hydrogen, hydrogen compounds such as methane (marsh gas), ammonia, and water vapor, and perhaps carbon dioxide. The composition of this atmosphere gradually changed. The gravitational attraction of the earth was not sufficiently strong to hold the lighter gas molecules, and they escaped into space. As the earth grew colder, gases which had been dissolved in the liquid rock escaped into the air, including water vapor, nitrogen and carbon dioxide. Oxygen appeared in the atmosphere, and it is believed that the original oxygen was formed by the separation of water into hydrogen and oxygen molecules in the upper atmosphere; after vegetation appeared on earth the plants began to put oxygen into the air. Earth's atmosphere now is nitrogen and oxygen, plus relatively small amounts of other gases.

On the celestial bodies, other things happened. The moon, with feeble gravitational attraction, was unable to hold any atmosphere at all. Jupiter and Saturn, large in size, and with much more powerful gravitation, retained atmospheres of hydrogen and hydrogen compounds.

Scientists believe that life on Earth began before its atmosphere was transformed from hydrogen and hydrogen compounds to oxygen and nitrogen, proving the feasibility of this

theory by laboratory experiments. In these, a mixture of gases similar to the primitive earthly atmosphere is prepared. Energy is applied to this mixture—energy in the form of electric spark, heat, ultra-violet light or charged particles. All of these forms of energy existed at the beginning of the world.

By this action, simple organic molecules are formed. This is not to say that the molecules are alive. They do, however, contain the constituent parts of living things.

Particularly, they contain amino acids, known as the building blocks of life. It is these building blocks, further developed to nucleic acids, which are passed from generation to generation. They contain the information on the future development of the species.

Scientists, in fact, can duplicate many of the individual steps through which life was created. But they cannot (or cannot yet) create actual life, for they lack two things in the laboratories which nature has in abundance.

These factors are: One, innumerable biochemical reactions and, two, time—the millions upon millions of years that nature had when swirling mists covered the hardening earth. At some point energy and biochemical materials combined under the right conditions—*and life began.* Nucleic acid molecules were formed and others followed. Due to errors in replication (i.e., in repetitions of the chemical combinations), and in mutation (alteration in form or qualities) there came in time to be different kinds of nucleic acid molecules. Thus began the process of different life formations and biological evolution.

Since this happened on earth in its most primitive days, it is more than likely it also happened on other planets. Of course, other things must be considered besides atmosphere—heat for example. Mercury, close to the sun, is too hot. Jupiter, Saturn, Uranus, Pluto and Neptune, far from the sun, may be too cold.

Or—they may not be. Also, it is possible that life of some completely different form than we know may have evolved—a carbonic biology unlike the definitely channeled biochemistry of earth organism, or possibly a biological system not based on carbon at all.

The NASA program of space exploration for the next few years holds great promise of solving one and perhaps both of these great twin mysteries—is there extraterrestrial life and what was the origin of life? American space technology is now developing the capability of exploring the moon and the planets of our solar system, to search there for organic matter and living organisms.

Spacecraft have been sent past the moon, and landed on the moon. Also, Mariner II, launched from Cape Canaveral on August 27, flew past Venus on December 14, taking readings and transmitting data which have significance in the search for extraterrestrial life. Mariner's measurements showed temperatures on the surface of Venus on the order of 800 degrees Fahrenheit, too hot for life as known on Earth. But temperatures at the top of the Venus cloud level are about minus 40 degrees. Could there be some form of life in the atmosphere between these levels?

Other flights past Venus and, also Mars, are planned. Later, instruments will be sent to Mars, Venus and the moon in the search for extraterrestrial life. Cultures, microscopes and other detecting devices will search out microbes and organisms. Eventually, television cameras will look for foliage and fossils—and, who knows, "footprints."

Among the search for life methods, devices or implements which NASA is utilizing are the following:

Optical Rotary Dispersion Profiles
The Multivator
The Vidicon Microscope
The J-Band Life Detector
The Radioisotope Biochemical Probe
Mass Spectrometer
The Wolf Trap
Ultraviolet Spectrophotometer

THE SEARCH FOR EXTRATERRESTRIAL LIFE

OPTICAL ROTARY DISPERSION PROFILES

This proposed method for searching out life in space involves the use of new techniques—some so new they have not been known to science before. They will be employed to seek out the one substance inextricably associated with life. That substance is deoxyribonucleic acid, usually known as DNA.

In order to determine the presence of life on other planets through instruments that are remotely controlled, two factors have to be considered.

First, we postulate that life on other planets has a similar chemistry to ours. Otherwise, we wouldn't know where to begin.

Second, what is life and how do you know when you've found it?

"This," says Dr. Ira Blei, "brings us to the heart of the problem of the search for life on other planets." Dr. Blei is the scientist in charge of the optical rotation experiment for NASA.

"How," he continues, "can one design single experiments which will provide enough information to permit a decision to be made concerning the existence of extraterrestrial life"?

"Life has become very difficult to define in just a few words. The highest form of life on earth, man, is a collection of very complex molecules having certain life-like properties associated with them."

"At the other end of the scale are the many types of simple chemical substances, for example, sugars, which are obviously not alive. Further, somewhere between the two extremes, molecules exist which are sometimes 'alive' and sometimes 'unalive'—the viruses."

"So, we may look for a property which is common to all things we would be willing to call living. That substance is DNA. It is apparently the key molecule which contains the coded heritable information passed on from one generation to the next—from the lowest forms of life up to man. If we find DNA on another planet through this experiment, we will accept that as evidence that life exists there."

Deoxyribonucleic acid is a giant, or polymer, molecule, built up by chemical combination of many similar small molecules. The final results look like a long string of beads of similar size and shape. The "beads" or individual units of the polymer are composed of three chemical compounds linked together with chemical bonds. These are: (1) nitrogenous bases, (2) a sugar, and (3) phosphoric acid.

One of the most useful physical-chemical techniques in identification of complex substances is absorption spectroscopy. This technique is based on the fact that complex molecules absorb light only at characteristic wavelengths. For instance, a dye is a complex organic molecule which absorbs light at some wavelength located in the portion of the electromagnetic spectrum which can be detected by the eye. What one actually sees is a color complementary to that which is absorbed. This color is made up of all those wavelengths which are not absorbed by the dye.

Chemical substances which absorb visible light are very much in the minority and make up a small fraction of known compounds. Others absorb light in those portions of the spectrum which cannot be detected by the human eye, that is, the ultraviolet, and the infrared.

Fortunately, we have photoelectric cells which are sensitive to

this "invisible" light. By measuring the amount of light energy which is left after passing a beam of a particular wavelength through an absorbing solution, we can tell at what wavelength light is absorbed, and how much light is absorbed. These two pieces of information, the wavelength absorption, and the amount of energy absorbed per unit weight, are intrinsic properties of a substance just as the melting point or solubility help to define a compound.

The nitrogenous base of the fundamental unit of DNA has such an absorption band in the ultra-violet (2600 Angstroms).

By measuring the absorption of ultra-violet light in a solution made from a soil sample, we could detect the presence of the nitrogenous base, adenine, and so infer the presence of DNA, hence life.

However, it has recently been discovered that adenine may be synthesized "spontaneously" in artificial systems resembling pre-biological circumstances. Therefore, evidence of adenine's presence could not be considered absolute evidence of the existence of life. But we're not licked yet! There is one other spectroscopic-like property which depends on a characteristic of the adenine-sugar-phosphoric acid unit which has not as yet been reproduced in the laboratory.

That property is the optical rotary power conferred on the whole unit by the sugar portion.

To understand this attribute of matter—optical rotation—we must become familiar with a few facts on optics. We are all familiar with the fact that the properties of a beam or ray of light seem to be symmetrical, or the same from any position perpendicular to its direction.

A round pencil-like object bears a good resemblance to a beam of light, in this instance: if one grasped the object with both hands between thumb and forefinger and slowly rotated it, with eyes closed, it would not be possible, upon opening one's eyes, to tell whether the pencil had been rotated at all.

This ordinary type of light beam is called unpolarized. If we were now able to force the beam of light to vibrate only in one plane, it would not be symmetrical if rotated, but one would get the same effect as if a straight-edged ruler were rotated around its long axis. Another way of looking at this effect is to consider a light beam to consist of a train of flat waves which have no particular orientation in space. This can be illustrated by tying a piece of rope to a wall, and snapping it (back and forth, up and down) obliquely so as to send flat waves inclined at any angle perpendicular to an axis down the length of the rope.

Of course, light consists of continuous ripples but the single ripple in the rope is a good representation of a plane polarized beam of light. Now if we wanted to select one of the many plane waves possible, we could put a picket fence between us and the wall to which the rope has been tied. In this arrangement, only those waves, or ripples, parallel to the openings in the fence could get through.

This is precisely how a polaroid filter permits only parallel plane waves to pass through it, thus, producing a plane polarized beam of light.

How can you tell if a beam of light is plane polarized? In terms of the rope and fence—by placing another picket between the wall and the original fence. When the pickets of the second fence parallel and coincide to those of the first fence, the ripples can come through. If the second fence is rotated ninety degrees they cannot.

To test a light beam for polarization, you would look at it through a rotating polarizing filter. If the light were polarized there would be only two positions of the filter, 180 degrees apart, which would allow light to come through.

Certain natural materials, either crystalline or in solution, are able to twist a beam of plane polarized light as it passes through. Again using a straight-edged ruler as our flat light wave, these substances would cause the light path to resemble a slightly

twisted ruler with one end rotated slightly out of the plane of the other end.

To measure the ability of a substance to rotate plane polarized light, it is necessary to place the substance between two polarizing filters or prisms. Plane polarized light passes through the substance into the second filter which has been rotated so that no light can get through.

Now, if the natural material we mentioned can cause the plane ray to twist, some light will begin to leak through the second or analyzer prism. In order to restore the initial condition of *no light* coming through the analyzer prism, the light plane must be rotated through a certain angle.

This ability to rotate the plane of polarized light is associated with molecular structure in a unique manner, just as the absorption spectroscopic characteristics are unique. Not all materials are capable of rotating the plane of polarized light, but, fortunately, sugars are.

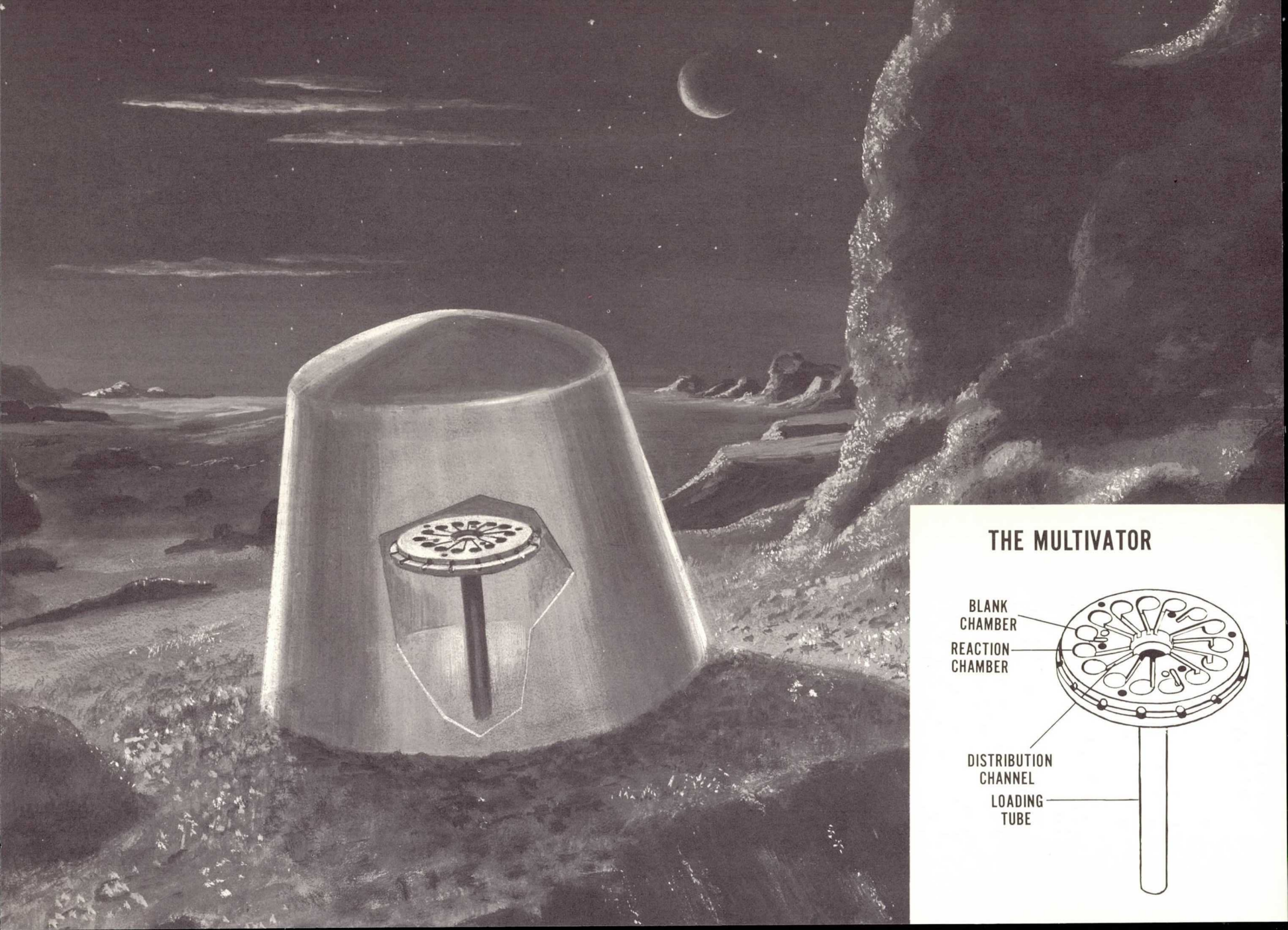
Further, when an optically active molecule chemically combines with an optically inactive compound, optical activity is conferred on the formerly inactive molecule. Another important feature of optical rotation is that this rotation is thousands of times greater near the spectroscopic absorption band of a substance than at wavelengths removed from it.

Adenine is not optically active, that is, possessing optical rotary power, but in chemical combination with a sugar, it becomes optically active.

This means that if one detects optical activity in a solution, in the wavelength region of the absorption band of adenine, it is excellent evidence that an adenine-sugar chemical bond is present.

Recalling our previous estimates of the improbability of an adenine-sugar bond being formed in anything but a living system, we infer that optical activity of a solution at the absorption band of adenine indicates the presence of DNA, hence life.

To recapitulate, if only adenine is present, there will be no optical activity at its absorption band. However, if the adenine-sugar bond is present, there will be a large optical activity at the same wavelength. Here then is the sensitive, unique property of the adenine-sugar-phosphoric acid unit of DNA which will give us the single, on-off signal that we require to determine that life in space exists.


THE MULTIVATOR
BLANK CHAMBER
REACTION CHAMBER
DISTRIBUTION CHANNEL
LOADING TUBE

THE MULTIVATOR LIFE DETECTION SYSTEM

A small device to perform experiments to determine whether there is life on Mars or the other planets is being designed by a team of biologists and instrumentation experts at Stanford Medical Center under the supervision of Dr. Joshua Lederberg.

The instrument is small enough to be carried to a planet as part of a capsule payload. It weighs only 1 pound, without the battery supply or the sample collector which will feed it material to test. It is housed in a metal tube 2½ inches in diameter and 10 inches long, making it smaller than a roll of paper towels commonly used at home.

The device is called a "multivator." It is a miniature, automated biological laboratory capable of performing a number of well controlled experiments. These are designed to demonstrate the presence or absence of microscopic life forms (bacteria, specifically) in a planet's soil.

Soil samples will be tested because experience on earth has demonstrated that if life exists anywhere, it is likely to be found in any pinch of soil as well as any drop of water or gust of wind and dust.

Information from the multivator will be such that it can be transmitted back to earth by radio.

Initially, experiments are planned to detect enzymes, or natural chemical catalysts, of types found in earthly bacteria. One such enzyme is called phosphatase; it breaks down phosphates, chemical compounds which are vital for living processes.

Soil samples will be blown into the multivator and mixed with a chemical which one of the enzymes will break down. The chemical has been tagged with a substance that will fluoresce or give off a characteristic color when broken down this way.

This is only one of the possible experiments with the multivator. It could also be used with radioactive tags, to measure a color characteristic of the result of a specific chemical test, or to measure the cloudiness or light scattering characteristics of a solution—all of which could be signs that bacteria have multiplied and therefore exist on a planet.

THE MULTIVATOR—The diagram (inset, page 8) shows the multiple-chamber feature of the Multivator Life Detection System, the mechanism of which may be seen within the capsule in the illustration. Dust is drawn up through the loading tube, and blown through the distribution channels to reaction chambers containing chemicals. If the dust contains microscopic life forms, chemical reactions will take place and signals will be sent to earth, as explained in the text. Control (blank) chambers contain reagents which cannot mix with the soil sample, so that it will be possible to check the condition of reagents after arrival on Mars.

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Certain chambers of the instrument are designed so they will not collect soil—to check the condition of the chemicals after the long trip through space. Others may be used to be sure the soil does not react with the chemical which is supposed to be produced by the enzyme-substrate reaction.

The scientists have attempted to be as certain as possible that the results of the experiments performed are meaningful. If the Martian soil destroyed the fluorescent effect, for instance, this would not mean life did not exist, but would clearly open avenues for further investigation.

All in all, 15 separate experiments could be carried out by the multivator, but they will probably be done in related groups of four or five to provide the best cross-check of results.

A small radio will transmit information to earth at about the same speed the multivator will generate it, doing away with the need for a more complex system which could store information before radioing it back.

The multivator operates as follows:

Dust carrying the samples (filtered to be sure no large particles entered which could clog the channels) is blown through the inlet tube and into the reaction chambers. (See diagram, page 8.) A sticky coating on the chamber walls collects the dust. Dust-free air exhausts out the port in the rear of the chamber. This technique collects about 95 percent of the dust in the aerosol. The aerosol inlet valve then closes to seal off the individual chambers.

A small rotation of the solvent chamber closes off the air exhaust ports and aligns solvent filling ports with those leading to the reaction chambers. Solvent is then injected into the reaction chambers. The substrates which have been stored dry in capsules are then dissolved and the reaction begins.

After a predetermined reaction time, fluorescent lamps go on in sequence and the amount of fluorescence is measured by the photomultiplier tube. This measurement is converted to a coded number and transmitted back to earth.

THE VIDICON MICROSCOPE

Dr. Joshua Lederberg's second project in the NASA search for life program is a vidicon microscope.

It consists of a lens system, a collection system, an illuminating system and a vidicon camera.

"This," says Dr. Lederberg, "is a search for *direct* evidence of life on Mars—the actual visualization of a microbe.

"In terrestrial atmospheres and on the surface of the Earth," he continues, "we find an abundance of viable or moribund micro-organisms, spores, diatoms, small multi-cellular organisms, colonial forms, pollen grains or fragments of organisms. The same may be true on Mars.

"While recognition of a microbe is not a simple matter, certain features are strongly indicative. Most terrestrial forms known have a regular geometric shape and occur within a certain size. Many organisms and cells have intricate architecture which can be recognized.

"This is true on Earth and is perhaps true on Mars. A number of bacteria, fungi, algae, protozoa, molds and other higher plants produce spores as part of their life cycles. Since these forms may be expected to survive rigorous conditions, the possibility of collecting spores is likely."

Dr. Lederberg also believes it will be interesting and valuable to discover and study the nature of Martian atmospheric dust. It would be useful in determining the character of the Martian surface, mineralogy, possible erosion and the nature of Martian chemistry itself.

It is expected that the first scientific packages landed on Mars will be ejected from a passing satellite. The scientific instruments in these packages will collect information on the way down and after they have landed on the Martian surface. In missions requiring large transmitters or a great deal of information storage the information will be telemetered to the satellite, or "bus" as it is called, which will then relay the data back to Earth. This relay operation makes it unnecessary for the small "rough landed" package to carry along the heavy equipment which would be required for direct transmission to Earth. The bus, even though it goes on by, will be much closer.

Dr. Lederberg's microscope will be capable of collecting dust particles during the 10 minutes required for descent from satellite to Mars as well as after it lands, of course.

Along with all the other search for life devices, the microscope must be able to withstand acceleration of the launch vehicle and the various temperatures it will encounter from launch, through space, to landing. It also must be capable of surviving sterilization, for extreme care is taken with all vehicles designed for planetary landings that they do not in any way contaminate these unknown areas.

The microscope, which will not look at all like the normal laboratory microscope, will be constructed and will operate very much as follows:

It will use a fixed focus lens. There will be a lighting system to illuminate the microscope's viewing stage. The lens system will be able to cover an object field of 100 microns with a resolution of 0.5 microns. The vidicon apparatus will transmit pictures with a delineation of at least four shades of grey. It will have 200-line scan to match the resolutions of the lens system.

The views taken by the vidicon apparatus will be transmitted to a capsule-size telemetry system for relay by radio to the satellite and thence back to Earth.

Several different collection systems considered for the microscope include impactors, impingers, thermal precipitators, ion and electrostatic precipitators. In each case the concentrated particles of Martian dust will be collected and funneled onto the stage of the microscope.

Dr. Lederberg estimates his instruments can be designed to weigh less than 3 pounds and have a volume of not more than 500 cubic inches. Power for illumination will not exceed one watt.

More elaborate microscopes are also being investigated which will include automatic focusing, change of magnification, and ultraviolet absorption analysis or ultraviolet microspectrophotometry.

THE J-BAND LIFE DETECTOR

This experiment is being conducted for NASA by two biochemists, Dr. L. P. Smith and Dr. R. E. Kay, and is designed for use on Mars and Venus.

"The primeval form of life on Earth is believed to have been protein-centered, just as it is now," said Dr. Smith. "Since conditions were similar on other planets, it is reasonable to expect the same chemical constituents there." The J-band experiment takes advantage of this assumption in the following manner:

J-bands are the intense absorption bands, of extremely high wave length, of certain cyanine dyes. Cyanine is a derivative of cyanide.

These J-bands appear, under special conditions, in the visible region of the spectrum and at longer wavelength than the ordinary absorption bands.

They are apparently caused by the transfer of energy between molecules, due to excitement.

When a protein is introduced into a solution of the dye, this dye is absorbed along the chain-like structure of the molecule. This in turn causes the excitment of the molecule necessary for the formation of the J-band.

Since protein is recognized as a basic ingredient in the formation of life, the J-band theory is a natural proposal. A J-band solution may be carried or mixed in a device which will be sent to Mars or Venus. Atmospheric or surface dust will be introduced into the solution.

If J-bands are then formed, it will be plain evidence that the atmospheric or surface dust contained protein and thus the assumption can be made that life exists on the planet.

The method for the detection of these J-absorption-bands is reasonably technical, although it is the usual method used for the detection of all absorption bands in the visible region of the spectrum.

Mono-chromatic light, that is, light which has one single color, will be obtained from any visible light source, Martian or Venusian daylight for example. This light, which might enter the device from any kind of aperture, will be filtered through a diffraction grating to reduce it to a mono-chromatic or single color state. This in turn will be passed through the dye solution and focused on a photo tube, a photo cell, or some similar detector.

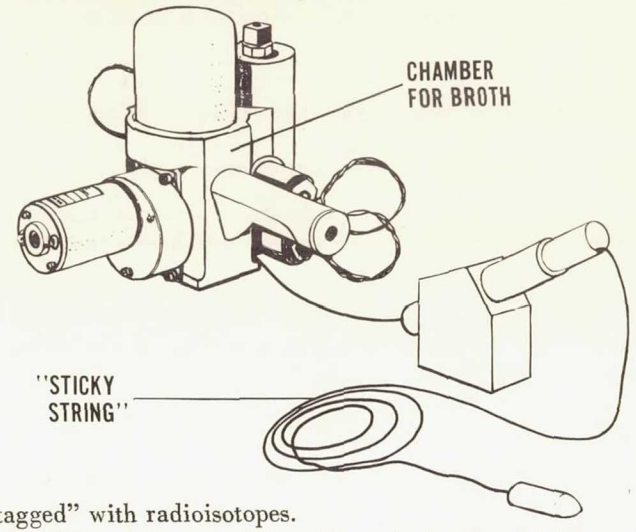
When protein is introduced into the dye solution via planetary dust, a J-band will form and light energy will be absorbed, causing a change in the electric current generated by the detector, which will be metered.

The change in the electric current would of course be telemetered back to Earth.

Planetary dust should be readily available on the surface and might consist of soil types, minerals or inorganic salts. There are several methods available to introduce the dust into the solution. The proteins accompanying the dust could be viruses, bacteria, fungi, algae, spores or pollen.

GULLIVER—This life detection device has three "sticky strings," as shown in the drawing on the page opposite. Only string one is indicated in the diagram. The strings are carried out in three different directions by bullets, then are reeled back, carrying particles of soil and microorganisms clinging to the sticky substance. The string is drenched with a nutrient broth (chamber for broth). If bacteria are present they will grow in the culture broth, and signals will be sent to earth. (See text.)

GULLIVER-MODEL MARK II



RADIOISOTOPE BIOCHEMICAL PROBE—"GULLIVER"

This project, which will search for life on planetary surfaces, involves the use of a "Mars universal culture medium" which has been "tagged" with radioisotopes, and a modified Geiger counter to detect the presence of living organisms.

The project scientists for NASA are Dr. Gilbert V. Levin, and Dr. Norman Horwitz, who evolved the radioisotope probe from experiments employed in testing public drinking water. The radioisotope probe also is known as "Gulliver."

When samples of water, or any other substance, are placed in a broth or similar culture medium, it takes a minimum of 48 hours for the incubation of bacteria.

When the medium has been treated with radioisotopes, and thus made mildly radioactive, this process is speeded up many times, Levin found. Definite results can be obtained in a maximum of 4 hours and frequently less.

The "Gulliver" experiment is carried out as follows:

A universal broth of medium is prepared in which almost any form of bacteria will grow. Several of the ingredients are "tagged" with radioisotopes.

Particles of dust are induced into the broth, which has previously been made sterile and contains no living matter.

As the living organisms begin to grow and multiply in the broth, they produce radioactive gas.

The gas activates the minature Geiger counter near the broth container. It begins clicking.

The Geiger counter is connected with a telemetering device which transmits signals of this activity.

The gas from the broth, and the resultant signals, not only indicate the presence of growing organisms but measure the number present.

The radioisotope probe is designed for use in a capsule which will land on Mars. The probe will be parachuted to the planetary surface as part of a larger scientific "package."

This package may be in the shape of a cone, much like the nose of a shell, or the nose cone of a ballistic missile. It will contain several experiments. The radioisotope device will be

inside the cone. The instrument is tiny for the job it has to do, some five inches across the base and only a little taller. It will weigh about three-fourths of a pound, thus taking up very little of the precious weight and room, of the overall capsule.

The radioisotope device has three basic units—a retriever mechanism, a reaction chamber and a counting and signaling system.

The collection or retriever mechanism consists of three fifty-foot lines wound on spools. Each line will have a tiny power projectile, or bullet, to unreel it.

The lines will be coated with some sticky substance, such as glycerol. This substance must remain sticky at low temperatures because the Martian weather ranges from about 50 degrees F. at noon on the Martian equator, to about 90 degrees below zero F. at the same place at night. As a matter of fact the entire package will be built to withstand temperatures as low as minus 200 degrees F. (Minus 70 degrees is about as low as an earthly thermometer drops even at the North Pole.)

The counting system is the transistorized Geiger counter.

When the instrumented space package arrives on Martian soil tiny ports or windows in the capsule wall will open; and the projectiles will fire, carrying the sticky strings out 50 feet.

As the strings reach their full distance, the tiny bullets at the end break off. At this same moment a miniature motor starts up and reels the strings back. The reason, of course, for having three is to triple the chance of success. Should one or two snag or strike obstacles the other, or others, could complete the experiment.

As they are reeled in, the lines are led through a hole in the bottom center of the incubation chamber. They bring in the particles of soil which will have clung to the sticky coating. After the strings have been drawn through, the hole is automatically sealed. At this moment the ampoule which has carried the broth on the 300-day journey to Mars will be broken by a plunger (powered by a dimple motor) and released onto the reeled up string.

A heating device controlled by a thermostat will keep the broth-soaking string at its best temperature for growth and metabolism.

All of the above operations will be controlled by a miniaturized programmer.

If the soil contains any living organisms, they should begin to grow within 4 hours. This growth will cause an increase in the production of radioactive gas. The radioactivity will be noted by the Geiger counter. A radio device attached to the Geiger counter will telemeter this information to the "bus." The "bus" will relay the information about life on Mars back to earth, along with literally miles of other tape recorded signals received from the overall Martian package. Another possible system would relay the signals directly from Mars to earth.

The radioisotope biochemical probe has been built and subjected to a number of tests. In one of these it was tested on a frosty morning in Rock Creek Park, Washington, D.C. and operated by remote radio control.

One of the projectiles hit a tree, but this did not hinder the successful operation. Both lines were reeled in and doused with culture. Bacterial growth started within 1 hour and continued.

MASS SPECTROMETER

The amino acids (NH_2 Group), as we learn from the study of chemistry, are principal components of proteins. Several of these amino acids are essential to human nutrition. The first amino acid was discovered in 1806 and more than 30 have been found since.

The Mass Spectrometer project is a feasibility study NASA is carrying out under the supervision of Dr. Klaus Beimann. If it performs well under laboratory tests here on earth, then a device will be built to duplicate these tests on one or more planets in the search for extraterrestrial life.

Through this study it is hoped to learn if amino acids and peptides can be identified via the mass of their pyrolysis products. Known amino acids will be heated on a metal strip near the ion source of the mass spectrometer. The molecular fragments vaporizing off the sample will be accelerated according to their mass onto an oscilloscope. Through this it will be possible to establish the temperature range at which the products give off the most readily recognizable high mass constituents, such as an ester.

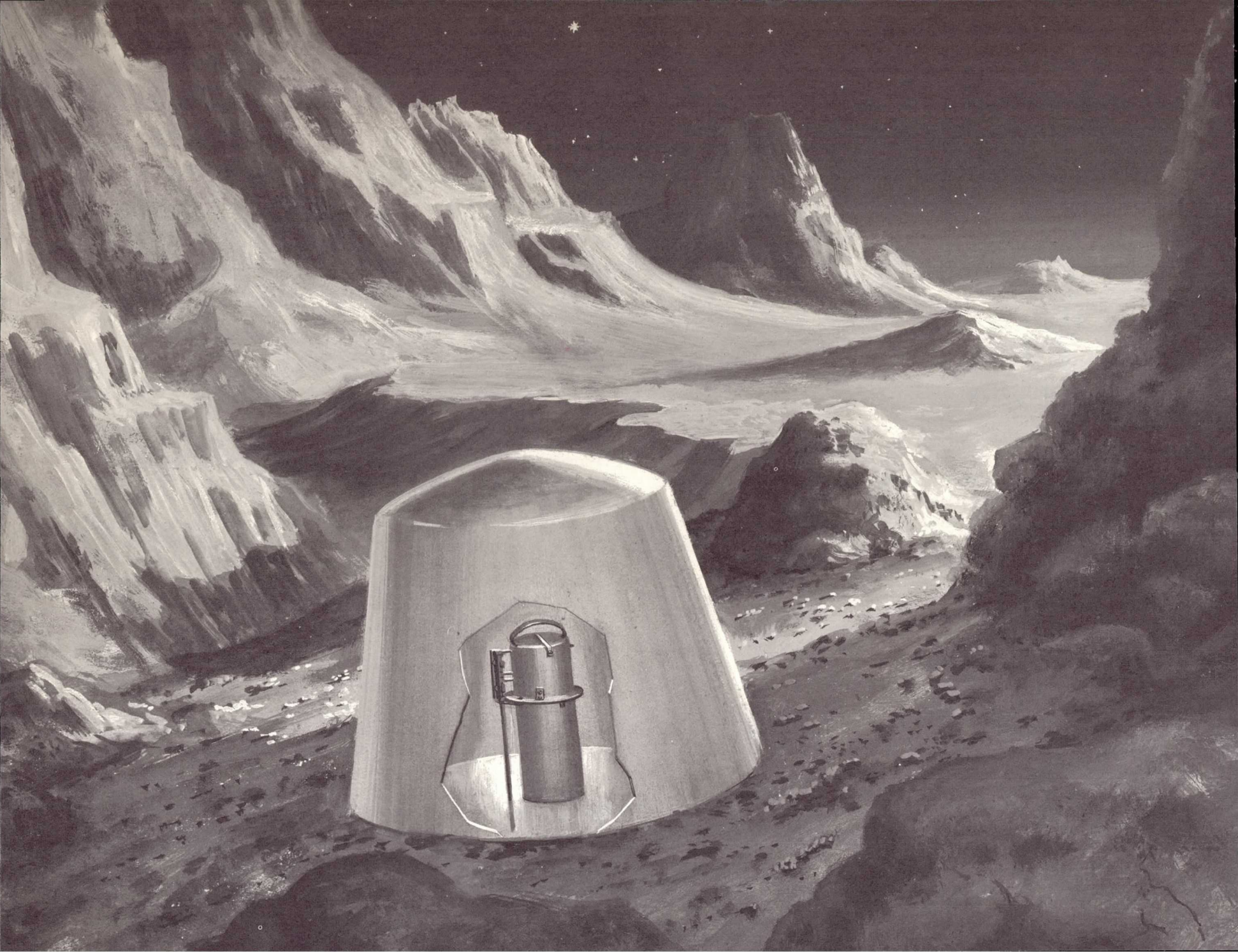
"Then," says Chemist Beimann, "we can follow the same procedure for all common amino acids, and some peptides and proteins of known amino acid composition. Through this we can evaluate the degree of information obtainable in this manner."

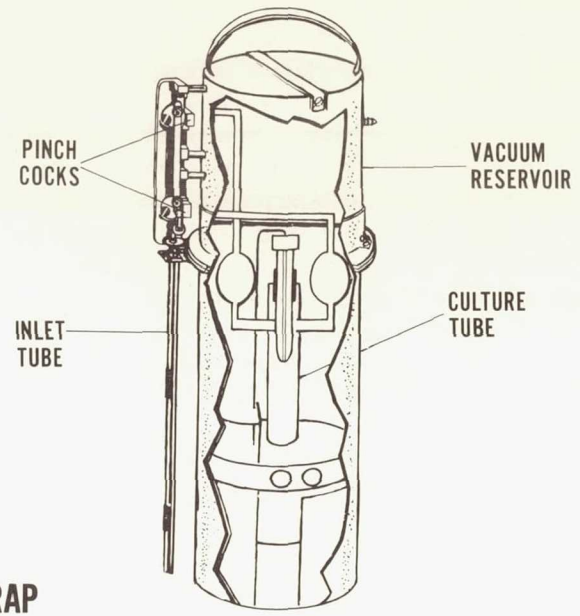
Dr. Freeman Quimby is Chief of Exobiology (life outside earth) Programs for NASA and is in charge of the search for life in space experiments. Of the Mass Spectrometry experiment he says:

"In addition to its possible use for detecting biologically significant molecules, as we know them, this device may lend itself to the detection of complex life-related substances which are not necessarily like our familiar organic compounds on earth."

That is, the experiment might detect a form of life *as we do not know it.*

Any Mass Spectrometry device built for use in space would, of course, incorporate a collection apparatus for sampling, sensors to note the results and telemetry equipment to communicate these results back to earth. Such information would be obtained quickly with this instrument. The entire spectrum of a biological molecule can be scanned in a fraction of a second.





THE WOLF TRAP—The inlet tube descends to the level of the ground, its tip shatters, and vacuum action draws soil samples up into the mechanism. The samples drop into the culture tubes, and if bacteria are present they will grow and be sensed and reported, as explained in the text.

THE WOLF TRAP

When Professor Wolf Vishniac conceived his search for life in space device, he called it the "bug detector." It was inevitable, however, that his biologist friends would rename it the "Wolf Trap."

His device is designed for the detection of life on Mars.

The Wolf Trap's principal component is a hollow tube from which air has been removed to create a vacuum. One end of the tube is extended into a fragile probe so that when it strikes the surface of Mars the tip will shatter. The internal vacuum will then suck dust into the tube. Inside the cylinder there will be exposed culture media in which bacteria can grow, or at least, as Professor Vishniac says, *some* bacteria *might* grow.

When the atmospheric pressure within the tube is equal to that outside, the opening will be closed by a spring-loaded valve. This will prevent evaporation of the culture media and any possible contamination of the planetary surface by the terrestrial organic matter inside.

If the experiment is successful and bacterial growth results, there will be two likely results: (1) The turbidity of the media will increase. (2) The acidity will change. These changes will be detected by incorporated sensing devices—the change in turbidity by a photoelectric cell and the change in acidity by a percentage of hydrogen ion (pH) electrode, a simple device for measuring the amount of electricity present in an acid solution.

When either or both of these changes occur, the sensors will communicate this fact to a telemetering device, with the results being relayed back to Earth.

"The principle of the Wolf Trap," says Professor Vishniac, "is susceptible to a variety of modifications. The first device will be as simple as possible.

"After the successful construction of the first model, we can elaborate on it. First, many varied media may be provided to search for different types of micro-organisms, including photosynthetic bacteria.

"Second, the response of the signaling device could be changed from a simple yes-no answer device to a more complex response. The change in turbidity as a result of bacterial growth, which would result in a change in light intensity registered by the photocell, could be coupled to a change in frequency in the signaling device.

"The variation of the signal would be the measure of the growth of bacteria. From this it would be possible to plot a growth curve. Similarly, a change of acidity might be signaled by the pH electrode in terms of rate of change—rather than a simple yes-no signal."

Professor Vishniac notes that his Wolf Trap is not foolproof, as, indeed, are none of the other search for life devices.

Suppose, for instance, the Wolf Trap lands on Mars and almost immediately upon impact the signals show a marked change in the culture medium. The signals show dense turbidity. The pH factor increases greatly.

About all that would mean, says Professor Vishniac, would be that the Martian surface is extremely dusty and the dust extremely acidic. However, if only a few of the signals indicate change, and more changes are signaled in the course of several hours a day, then it can be reasonably concluded that some gradual changes have taken place as a result of bacterial activity.

Professor Vishniac's Wolf Trap is designed to be built of plastic—probably polypropyline. This material is almost transparent and yet is resistant to most chemicals and is shatterproof. All of the electrical components needed for the Wolf Trap will be transistorized and housed in a light metal shell.

ULTRAVIOLET SPECTROPHOTOMETER

This is a device to "explore the feasibility of investigating the qualitative and quantitative aspects of the spectrophotometry of proteins and peptides in the vicinity of the absorption maximum of the peptide bond, that is, between 180 and 220 millimicrons."

Before going further, it might be well to review a few terms. For example:

Photospectrometry is the science of comparing the intensities of the corresponding colors of two spectra (plural of spectrum).

The **spectrum** is, of course, the series of images formed when a light beam is dispersed and then brought to focus, so that the component waves are arranged in the order of their wavelengths.

A **protein** can be defined as any of a class of complex combinations of the amino acids which are the essential constituents of all living cells.

The **peptide** is the bond which unites groups of amino acids.

The NASA experiment in ultraviolet spectrophotometry is under the supervision of Dr. Ira Blei, who also is conducting the optical rotary dispersion profiles project.

One of the most dependable ways to identify organic compounds is by their absorption spectrum.

The phenomenon of color is a small part of this general property of the absorption of light of all wavelengths, visible and invisible, by organic molecules.

"There are several concepts," says Dr. Blei, "which require explanation before absorption spectroscopy and its application to the detection of extraterrestrial life can be understood.

"This can perhaps best be done by using a familiar analogous process. Picture a room with two pianos, one with a complete set of strings. The other has only three strings, the middle C string, which, when struck, vibrates 440 times each second, and perhaps two other strings. One of these vibrates at a higher frequency and one vibrates at a lower frequency.

"Now let us strike the keys on the first complete piano, one at a time, starting at the highest frequency and descending in a regular manner the musical scale, which is analogous to the optical spectrum.

"Only when a frequency is sounded on the first piano, which is identical to that of one of the three strings on the second piano, will those second piano strings vibrate.

"Organic molecules exhibit the same behaviour with respect to light."

Visible light is a small part of the electromagnetic spectrum. The eye can detect those frequencies which are called visible, but one must use sensitive photo-electric devices to detect the light of frequencies which are "invisible," ultraviolet or infrared light.

Organic molecules respond only to certain frequencies of light, the most characteristic of which lie in the region of the spectrum known as the ultraviolet. This light is at a much higher frequency than, for instance, blue visible light, which, by comparison, is in turn at a higher frequency than red visible light.

"As light of decreasing frequency," continues Dr. Blei," is passed through a solution of organic molecules, some frequency will be reached which causes the molecules to vibrate. The amount of light energy coming out of the solution at that frequency will be markedly reduced.

"Continuing down the spectrum, the light can be passed through the solution again and again unattenuated.

"In this way one can identify substances and also measure concentrations, because different materials absorb different amounts of light when compared, gram for gram. Particularly is this true of the peptide bond."

Apparatus is being built and studies conducted which will determine the feasibility of this approach to acquiring information about extraterrestrial life.

ANALYSIS OF ANCIENT SEDIMENTS

In this NASA experiment, carried on as a supplement to the eight search for life projects, two U.S. oil companies will conduct analyses of ancient sediment and biological samples (hydrocarbons and mineral aggregates) all over the Earth so that they can be compared with similar readings obtained from planets by remote instrumentation.

The techniques which will be used on the planets (and probably the Moon) may take the form of gas chromatography, mass spectroscopy, infrared or ultraviolet spectroscopy—singly or in combination.

The comparison of earthly samples with similar materials from the planets can return a great deal of information about the origin of the solar system and the early formations, temperatures, atmospheres and even ages of individual planets, including Earth.

THE MARS MARINER

The first device to search for indirect evidence of life on Mars will be carried by Mariner C, a NASA planetary flyby scheduled for 1964.

Mars and Earth both orbit the Sun in the same direction, but not at the same speed or distance. The mean distance of Earth from the Sun is 90 million miles while the mean distance of Mars is 141 million miles. The Earth makes one revolution about the Sun each 365 and ½ days while Mars takes 687 Earth days to make the same trip.

Mars can be as far away from Earth as 62 million miles—or as close as 34 million miles when their two orbits bring them into what astronomers call favorable opposition—that is, closest together.

Mariner C will not land on the planet, but will fly past it at a distance of about 10,000 miles. It will carry instrumentation to obtain data on interplanetary phenomena and to take high quality television photographs of Mars along with infrared spectra.

A later Mariner will carry the first of the search-for-life devices to Mars in 1966–67. The instrumented package will land on the Martian surface by parachute.

The final dimensions of the Mariner C will be similar to Mariner II, which flew past Venus on December 14, 1962.

The hexagonal framework of Mariner II housed a liquid fuel rocket motor for trajectory correction. It had six modules or compartments containing the attitude control system, electronic circuitry for the scientific experiments, power supply, battery and charger, data encoder and command subsystem for receiving and obeying signals from Earth, digital computer and sequencer, and radio transmitter and receiver.

The solar panels, with 9,800 solar cells, collected energy from the Sun and converted it into electrical power. Two-way communications were supplied by the receiver/transmitter, two transmitting antennas and the command antenna for receiving. Stabilization for yaw, pitch and roll was provided by ten cold gas jets, mounted in four locations and fed by two titanium bottles.

U.S. GOVERNMENT PRINTING OFFICE : 1963—O-691-542

THE SEARCH FOR EXTRATERRESTRIAL LIFE

is an informational publication of

The National Aeronautics and Space Administration

Washington 25, D.C.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION